Sensor Systems

of the

NASA Airborne Science Program

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The National Aeronautics and Space Administration maintains a variety of aircraft and sensor systems dedicated to the support of remote sensing research. Two Lockheed ER-2s (S-model U-2,) a DC-8, and several U.S. Dept. of Energy aircraft provide multi-level platforms for both NASA and investigator-owned sensors. Data are collected for the atmospheric, land, and ocean processes aspects of the NASA Earth Science program, as well as for universities and other government agencies. Several of these systems are being used to validate algorithms for the NASA Earth Observing System.

The NASA aircraft, located at Dryden Flight Research Center, are used as test-beds for advanced sensor design and satellite simulation, as well as to support scientific and operational data collection campaigns.   Numerous sensor systems are in use and under development by NASA, including multispectral imaging devices, a SAR system, and a suite of large-format mapping cameras. All instruments are spectrally, spatially, and radiometrically calibrated on a routine basis. The aircraft themselves are equipped with navigation systems that continuously record GPS location and platform attitude data.

The systems described here are facility NASA sensors, and are generally available to the science community; they reside at either Ames Research Center or the Jet Propulsion Laboratory (noted as ARC or JPL, respectively.) There are a variety of other sensors that fly on these aircraft that are owned by individual investigators, which are not within the scope of this document.

AVIRIS (Airborne Visible and Infrared Imaging Spectrometer - JPL)

The AVIRIS is the second in a series of imaging spectrometer instruments developed at the Jet Propulsion Laboratory (JPL) for earth remote sensing. This instrument uses scanning optics and four spectrometers to image a 614 pixel swath simultaneously in 224 contiguous spectral bands.

AVIRIS parameters are as follows:

IFOV:	1 mrad
Ground Resolution:	66 feet (20 meters) at 65,000 feet
Total Scan Angle:	30 degrees
Swath Width:	5.7 nmi (10.6 km) at 65,000 feet
Digitization:	12-bits

Spectrometer	Wavelength	#Bands	Bandwidth
1	0.41 - 0.70 µm	31	9.4 nm
2	0.68 - 1.27 µm	63	9.4 nm
3	1.25 - 1.86 µm	63	9.7 nm
4	1.84 - 2.45 µm	63	9.7 nm

Notes: This instrument is flown on the ER-2 aircraft. All data collection missions are coordinated through JPL.

(See the AVIRIS homepage at http://makalu.jpl.nasa.gov/aviris.html)

MODIS Airborne Simulator (ARC)

The MODIS Airborne Simulator (MAS) is a multispectral scanner configured to approximate the Moderate-Resolution Imaging Spectrometer (MODIS), an instrument to be orbited on the NASA EOS-AM1 platform. MODIS is designed to measure terrestrial and atmospheric processes. The MAS was a joint project of Daedalus Enterprises, Berkeley Camera Engineering, and Ames Research Center. The MODIS Airborne Simulator records fifty spectral bands, configured as follows:

Spectral Channel	Band center (μm)	Bandwidth (μm)	Spectral Range	Spectral Channel	Band center (μm)	Bandwidth (μm)	Spectral Range
1	0.4649	0.0397	0.4451-0.4848	26	3.1192	0.1616	3.0384-3.2000
2	0.5494	0.0417	0.5285-0.5703	27	3.2809	0.1486	3.2066-3.3552
3	0.6550	0.0511	0.6294-0.6805	28	3.4330	0.1617	3.3521-3.5138
4	0.7024	0.0415	0.6816-0.7231	29	3.5940	0.1539	3.5170-3.6709
5	0.7431	0.0420	0.7221-0.7641	30	3.7449	0.1449	3.6724-3.8174
6	0.8248	0.0427	0.8034-0.8461	31	3.9069	0.1602	3.8267-3.9870
7	0.8667	0.0414	0.8460-0.8874	32	4.0707	0.1554	3.9929-4.1484
8	0.9072	0.0409	0.8867-0.9276	33	4.1699	0.0669	4.1365-4.2034
9	0.9476	0.0397	0.9277-0.9674	34	4.4029	0.1255	4.3401-4.4656
10	1.6422	0.0519	1.6163-1.6682	35	4.5404	0.1512	4.4648-4.6160
11	1.6975	0.0505	1.6722-1.7228	36	4.6979	0.1591	4.6184-4.7775
12	1.7499	0.0506	1.7245-1.7752	37	4.8536	0.1516	4.7778-4.9294
13	1.8014	0.0491	1.7768-1.8259	38	5.0033	0.1468	4.9298-5.0767
14	1.8548	0.0489	1.8303-1.8792	39	5.1588	0.1400	5.0888-5.2288
15	1.9044	0.0487	1.8801-1.9288	40	5.3075	0.1327	5.2412-5.3738
16	1.9553	0.0483	1.9312-1.9794	41	5.3977	0.0755	5.3590-5.4365
17	2.0048	0.0487	1.9804-2.0291	42	8.5366	0.3950	8.3391-8.7341
18	2.0551	0.0484	2.0309-2.0793	43	9.7224	0.5365	9.4541-9.9906
19	2.1037	0.0486	2.0794-2.1280	44	10.5071	0.4579	10.278-10.736
20	2.1532	0.0483	2.1291-2.1774	45	11.0119	0.4710	10.776-11.247
21	2.2019	0.0481	2.1779-2.2259	46	11.9863	0.4196	11.776-12.196
22	2.2522	0.0486	2.2278-2.2675	47	12.9013	0.3763	12.713-13.089
23	2.3021	0.0487	2.2777-2.3265	48	13.2702	0.4584	13.041-13.500
24	2.3512	0.0476	2.3274-2.3750	49	13.8075	0.5347	13.540-14.075
25	2.4005	0.0483	2.3764-2.4246	50	14.2395	0.3775	14.051-14.428

Sensor/Aircraft Parameters:
        Spectral Bands: 50 (16-bit resolution)
        IFOV: 2.5 mrad
        Ground Resolution: 163 feet (50 meters at 65,000 feet)
        Swath Width: 19.9 nmi (36 km)
        Total Scan Angle: 85.92 degrees
        Pixels/Scan Line: 716
        Scan Rate: 6.25 Hz
        Ground Speed: 400 kts (206 m/second)
        Roll Correction: Plus or minus 3.5 degrees (approx.)

(See the homepage at http://ltpwww.gsfc.nasa.gov/MODIS/MAS/Home.html)

MASTER (MODIS/ASTER Airborne Simulator - ARC)

The MASTER is similar to the MAS, with the thermal bands modified to more closely match the NASA EOS ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite instrument, which is scheduled for launch in 1998. It is intended primarily to study geologic and other Earth surface properties. Flying on both high and low altitude aircraft, the MASTER will be operational in early 1998. Its fifty spectral bands are configured as follows:

Spectral Channel	Band center (µm)	Bandwidth (µm)	Spectral Range	Spectral Channel	Band center (µm)	Bandwidth (µm)	Spectral Range
1	0.460	0.04	0.440-0.480	26	3.150	0.15	3.075-3.225
2	0.500	0.04	0.480-0.520	27	3.300	0.15	3.225-3.375
3	0.540	0.04	0.520-0.560	28	3.3450	0.15	3.375-3.525
4	0.580	0.04	0.560-0.600	29	3.600	0.15	3.525-3.675
5	0.660	0.06	0.630-0.690	30	3.750	0.15	3.675-3.825
6	0.710	0.04	0.690-0.730	31	3.900	0.15	3.825-3.975
7	0.750	0.04	0.730-0.770	32	4.050	0.15	3.975-4.125
8	0.800	0.04	0.780-0.820	33	4.200	0.15	4.125-4.275
9	0.865	0.04	0.845-0.885	34	4.575	0.6	4.275-4.875
10	0.905	0.04	0.885-0.925	35	4.500	0.15	4.425-4.575
11	0.945	0.04	0.925-0.965	36	4.650	0.15	4.575-4.725
12	1.625	0.05	1.600-1.650	37	4.800	0.15	4.725-4.875
13	1.675	0.05	1.650-1.700	38	4.950	0.15	4.875-5.025
14	1.725	0.05	1.700-1.750	39	5.100	0.15	5.025-5.175
15	1.775	0.05	1.750-1.800	40	5.250	0.15	5.175-5.325
16	1.825	0.05	1.800-1.850	41	7.900	0.4	7.70-8.10
17	1.875	0.05	1.850-1.900	42	8.300	0.4	8.10-8.50
18	1.925	0.05	1.900-1.950	43	8.700	0.4	8.50-8.90
19	1.975	0.05	1.950-2.000	44	9.100	0.4	8.90-9.30
20	2.075	0.05	2.050-2.100	45	9.700	0.4	9.50-9.90
21	2.160	0.05	2.135-2.185	46	10.100	0.4	9.90-10.30
22	2.210	0.05	2.185-2.235	47	10.625	0.65	10.30-10.95
23	2.260	0.05	2.235-2.285	48	11.300	0.7	10.95-11.65
24	2.3295	0.065	2.297-2.362	49	12.050	0.5	11.80-12.30
25	2.3945	0.065	2.362-2.427	50	12.750	0.5	12.50-13.00

Sensor/Aircraft Parameters:

Spectral Bands:	50 (16-bit resolution)
IFOV:	2.5 mrad
Ground Resolution:	12-50 meters (variable w/ altitude)
Total FOV:	85.92 degrees
Pixels/Scanline:	716
Scan Rate:	6.25 - 25 Hz

(See the homepage at asterweb.jpl.nasa.gov)

AirMISR (Airborne Multi-angle Imaging SpectroRadiometer - JPL)

This is an airborne instrument for obtaining multi-angle imagery similar to that of the satellite-borne MISR instrument, which is designed to contribute to studies of the Earth's ecology and climate. AirMISR flies on the NASA-owned ER-2 aircraft. It was built for NASA by the Jet Propulsion Laboratory in Pasadena, California.

(See the homepage at http://www-misr.jpl.nasa.gov/armain.html)

AIRSAR (Airborne Synthetic Aperture Radar - JPL)

This is an experimental system managed by the NASA Jet Propulsion Laboratory (JPL,) that flies on the DC-8 aircraft. It simultaneously acquires data in the L, P, and C-Bands in multiple polarizations. The system was designed in support of the Space Shuttle Imaging Radar-C (SIR-C) program, but is widely used in the SAR remote sensing research community.

(See the homepage at http://southport.jpl.nasa.gov/airsardesc.html)

TMS (Thematic Mapper Simulator - ARC)

This is a Daedalus AADS-1268 scanner that flies on the ER-2 aircraft and simulates the LANDSAT TM instrument, with slightly higher spatial resolution, and several extra bands.

Band	Wavelength µm
1	0.42- 0.45
2 (TM1)	0.45- 0.52
3 (TM2)	0.52- 0.60
4	0.60- 0.62
5 (TM3)	0.63- 0.69
6	0.69- 0.75
7 (TM4)	0.76- 0.90
8	0.91- 1.05
9 (TM5)	1.55- 1.75
10 (TM7)	2.08- 2.35
11 (TM6) High Gain	8.5- 14.0
12 (TM6) Low Gain	8.5- 14.0

    Spatial Resolution: 25 meters (all bands) from 19.8 km (65,000 ft.)
    Total Field of View: 42.5 degrees
    IFOV: 1.25 mrad

Notes: All bands are 8-bit digitization; onboard blackbody sources are carried for thermal calibration. The system is scheduled to be upgraded to 16-bit resolution in late 1998.

(See the homepage at http://asapdata.arc.nasa.gov/Sensors.htm)

AOCI (Airborne Ocean Color Imager - ARC)

The AOCI is a high altitude multispectral scanner built by Daedalus Enterprises, designed for oceanographic remote sensing. It provides 10-bit digitization of eight bands in the visible/near-infrared region of the spectrum, plus two 8-bit bands in the near and thermal infrared. The bandwidths are as follows:

Channel	Wavelength, μm	Digitization
1	0.436 - 0.455	10 bit
2	0.481 - 0.501	"
3	0.511 - 0.531	"
4	0.554 - 0.575	"
5	0.610 - 0.631	"
6	0.655 - 0.676	"
7	0.741 - 0.800	"
8	0.831 - 0.897	"
9	0.989 - 1.054	8 bit
10	8.423 - 12.279	"

Spatial Resolution:	50 Meters from 19.8 km (65,000 ft.)
Total Field of View:	85 degrees
IFOV:	2.5 mrad

Note: The system is scheduled to be upgraded to 16-bit resolution in late 1998.

(See the homepage at http://asapdata.arc.nasa.gov/Sensors.htm)

MAMS (Multispectral Atmospheric Mapping Sensor - ARC)

The MAMS is a modified Daedalus Scanner flown aboard the ER-2 aircraft. It is designed to study weather related phenomena including storm system structure, cloud-top temperatures, and upper atmospheric water vapor. The scanner retains the eight silicon-detector channels in the visible/near-infrared region found on the Daedalus Thematic Mapper Simulator, with the addition of four channels in the infrared relating to specific atmospheric features. The spectral bands are as follows:

Channel	Wavelength, μm
1	(LSBs for Channels 9-12)
2	0.45 - 0.52
3	0.52 - 0.60
4	0.57 - 0.67
5	0.60 - 0.73
6	0.65 - 0.83
7	0.72 - 0.99
8	0.83 - 1.05
9	3.55 - 3.93 (6.20- 6.90 optional)
10	3.55 - 3.93 (" " ")

11	10.3 - 12.1
12	12.5 - 12.8

Spatial Resolution: 50 or 100 meters from 19.8 km (65,000 ft.)
Total Field of View: 85.92 degrees
IFOV: 2.5 or 5.0 mrad (selectable)

Notes: Channels 9 - 12 are digitized to 10 bits; all others are 8-bit. Blackbody sources are carried for IR calibration. The system is scheduled to be upgraded to 16-bit resolution in late 1998.

(See the homepage at http://wwwghcc.msfc.nasa.gov/irgrp/mams)

Electro-Optic Camera (ARC)

This is a three channel framing camera designed for the ER-2, consisting of three 2048 X 2048 element, cooled silicon arrays mounted on a prism behind a single lens. The channels cover the green, red, and near-IR portions of the spectrum; each channel can be further narrowed within its respective range with a removable narrow-band filter mounted on the dichroic prism face.

Channel	Wavelength, µm
1	.525 - .570
2	.620 - .700
3	.810 - .850

Total Field of View: 60 degrees
IFOV: 0.52 mrad
Digitization: 12 bits

(See the homepage at http://asapdata.arc.nasa.gov/Sensors.htm)

Aerial Camera Systems (ARC)

The ER-2 can carry a variety of film camera systems. Several of these cameras are calibrated for precision photogrammetry, and the film may be used to generate digital ortho-photos or high-resolution digital elevation models.

Camera Type	Lens	Film Format	Ground Coverage	Nominal Resolution	Scale
RC-10	6"/f4	9" X 9"	30 X 30km	3.0-8.0m	1:130,000
RC-10	12"/f4	9" X 9"	15 X 15km	1.5-4.0m	1:65,000
HR-732	24"/f8	9" X 18"	7.4 X 15km	0.6-3.0m	1:32,500
IRIS (Panoramic)	24"/f3.5	4.5" X 35"	3.7 X 40km (Nadir)	0.3-2.0m	1:32,500

Note: Spatial parameters are for the ER-2 at 19.8km altitude; actual resolution is a function of target contrast. Missions are typically flown with 60% forward frame overlap for stereo coverage. RC-30 cameras are also available on the Dept. of Energy aircraft.

(See the homepage at http://asapdata.arc.nasa.gov/Sensors.htm)

STARLink

The Satellite Telemetry And Return Link (STARLink) system provides real-time, continuos relay of digital sensor data from the ER-2 aircraft via the NASA Tracking & Data Relay Satellite System (TDRSS.) It is currently configured to send 48 Mb/sec of data to the ground station, and 400 Kb/sec simultaneously back up to the aircraft for sensor command and control. The system offers nearly global coverage, with the data being captured to disk arrays at Ames Research Center.

(See the homepage at http://hawkeye.arc.nasa.gov)

Other Imaging systems

The ER-2 and DC-8 aircraft are also equipped with video systems for tracking purposes, which are scheduled to be replaced by HDTV devices.

Data Availability

All of the data collected by these systems is publicly available through U.S. Government agencies. Archives exist at the EROS Data Center of the U.S. Geological Survey in Sioux Falls, South Dakota; and within the NASA EOS-DAACs (Earth Observing System - Distributed Active Archive Centers.) Further information is available from the NASA Ames Research Center Aircraft Sensor Facility at (650) 604-6252.

Flight Documentation and Data Archive Searches

The following is the web site for flight documentation as published by the Airborne Sensor Facility at NASA Ames Research Center:

> http://asapdata.arc.nasa.gov/er-2fsr.html

Additional information regarding flight documentation to include data archive searches may be obtained from the following:

> Airborne Sensor Facility
> MS 240-6
> NASA Ames Research Center
> Moffett Field, CA 94035-1000
> Telephone: (650)604-6252 (FAX 4987)